

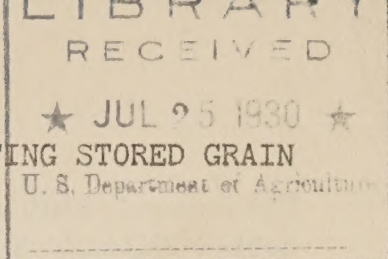
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## THE USE OF THE ETHYLENE OXIDE-CARBON DIOXIDE MIXTURE FOR TREATING STORED GRAIN

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For several years workers in the United States Department of Agriculture have been searching for a fumigant suitable for use in the treatment of stored grain. On account of fire hazard, excessive cost, ineffectiveness, toxicity to man, or deleterious effect on grain, the fumigants in general use up to the present time have not been entirely satisfactory and the operators of grain elevators have had to resort to handling the grain in order to keep it in condition.

During the past year a method of using ethylene oxide in combination with carbon dioxide has been developed that appears to be admirably adapted for the fumigation of grain in elevator bins. There is no fire hazard when the fumigant is applied as described in this paper, and the method of application is simple. In addition the fumigant has no harmful effects upon the milling and baking qualities of the grain, leaves no odor, is not expensive, can be handled without danger to the operator, and when properly applied is 100 per cent effective against the grain weevil even at winter temperatures.

The insecticidal value of ethylene oxide was first discovered by Cotton and Roark, who published an account of their experiments with it in 1928 (Ind. Eng. Chem., 20, 805, 1928). They found that it was highly toxic to insects and particularly well suited for the treatment of foodstuffs. At ordinary temperatures and pressures ethylene oxide is a colorless gas; at low temperatures and atmospheric pressure it is a mobile, colorless liquid, boiling at 10.5°C. The liquid is inflammable, but concentrations of the gas below 3.5 pounds per 1,000 cubic feet of space are nonexplosive.

Cotton and Young (Proc. Ent. Soc. Wash., 31, no. 5, 97-102, 1929) found that by mixing carbon dioxide with ethylene oxide the toxicity was considerably increased and the fire hazard reduced or eliminated according to the proportion of carbon dioxide used. Further tests by Back, Cotton, and Ellington (Jr. Econ. Ent., 23, no. 2, 226-231, 1930) indicated the desirability of using at least 7 pounds of carbon dioxide with 1 pound of ethylene oxide. Jones and Kennedy (Ind. Eng. Chem., 22, 146, 1930), of the Bureau of Mines, found that the vapor formed by a mixture of 7.15 parts by weight of carbon dioxide with one part of ethylene oxide was noninflammable.

The first attempt to use a mixture of ethylene oxide and carbon dioxide for the treatment of grain in elevator bins was made in Toledo, Ohio, in 1929. A large milling concern that had installed expensive equipment for the purpose of pumping a mixture of carbon disulphide and carbon dioxide into their tanks of grain decided to try the ethylene oxide-carbon dioxide mixture instead.



Their equipment consisted of a vacuum tank and pump. The ethylene oxide and carbon dioxide were drawn into the vacuum tank in the proportion of 1 pound of ethylene oxide and 7 pounds of carbon dioxide and the resulting mixture was pumped into the bottom of the tank of grain. Several fumigations were conducted with this equipment, using dosages ranging from 1.5 pounds to 2 pounds of ethylene oxide per 1,000 cubic feet of space. The results obtained, though not perfect, were very promising and further tests were planned. It was realized that the equipment used in Toledo was too expensive for practical purposes, and efforts were made to devise a simpler method of introducing the fumigant.

Attempts were made to introduce the fumigant by applying it directly into the stream of grain as the bins were being filled. In one instance the two gases were applied directly from cylinders, the materials being conducted through separate tubes leading into the top of the bin; in the other instance the ethylene oxide was mixed with "dry ice" (solid carbon dioxide) and the mixture poured into the grain as it entered the bin.

The use of "dry ice" as a source of carbon dioxide was suggested by chemists of the company manufacturing ethylene oxide, and this method has eventually proved to be most satisfactory. In the preliminary tests 1 pound of ethylene oxide was used with 7 pounds of the "dry ice" and the dosage was figured on the basis of 2 pounds of ethylene oxide per 1,000 cubic feet of bin space. As shown in tests Nos. 1 to 4, this dosage killed from 85 to 100 per cent of the insects in concrete, steel, and wooden bins, some of which were closed whereas others were open at the top. The results of these preliminary tests indicated the necessity for an increase in the dosage. Consequently, in subsequent fumigations the dosage was increased to 3 pounds of ethylene oxide per 1,000 bushels of grain. It was also decided to change the mixture of "dry ice" and ethylene oxide from a 7-to-1 ratio to a 10-to-1 ratio, so that the resulting product has a consistency resembling snow rather than being liquid.

Of the many fumigations conducted with the "dry ice" and ethylene oxide 10-to-1 mixture at the rate of 3 pounds of ethylene oxide or 33 pounds of the mixture per 1,000 bushels of grain, all but two cases have shown a 100 per cent kill, both in the planted test lots of insects and in the composite samples. Of the two exceptions one showed a 98.7 per cent kill and the other a 98.1 per cent kill; two "bran bugs" (flour beetles) were found alive in one trap, and a few weevils were alive in another bag placed directly on the gate of the bin. Details of some of these fumigations are given in the following pages.

#### Method of Applying the Fumigant

The following method of applying the ethylene oxide - "dry ice" mixture has been developed as a result of cooperative work between members of the Bureaus of Entomology, Chemistry and Soils, and Agricultural Economics of the United States Department of Agriculture, The Grain Inspection Department of the New York Produce Exchange, and the manufacturers of ethylene oxide. Through the courtesy of Mr. Laurel Duval, chief grain inspector of the New York Produce





FIG. 1 - FORTY-POUND CAKES OF "DRY ICE" IN BOX. BY PERMISSION OF LAUREL DUVAL, CHIEF GRAIN INSPECTOR, NEW YORK PRODUCE EXCHANGE



FIG. 2 - BREAKING UP THE "DRY ICE" BEFORE MIXING WITH ETHYLENE OXIDE







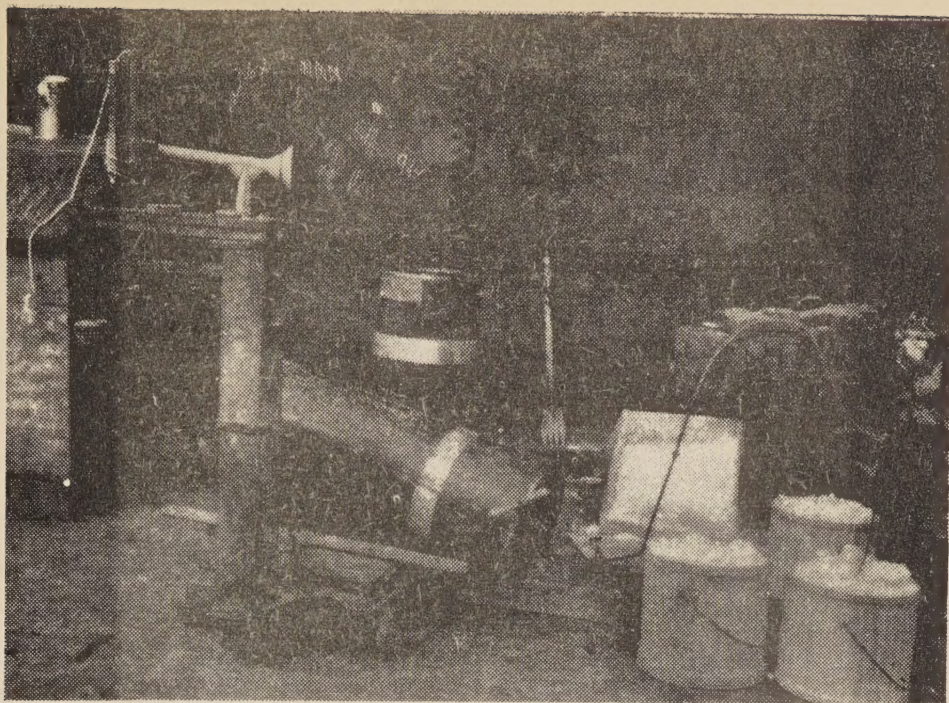


FIG. 3 - ETHYLENE OXIDE BEING WEIGHED INTO CANS OF CRUSHED "DRY ICE" FROM TANK ON PLATFORM SCALE. NOTE HAND PUMP WHICH IS USED TO CREATE THE PRESSURE NEEDED TO FORCE THE LIQUID OUT OF THE CYLINDER

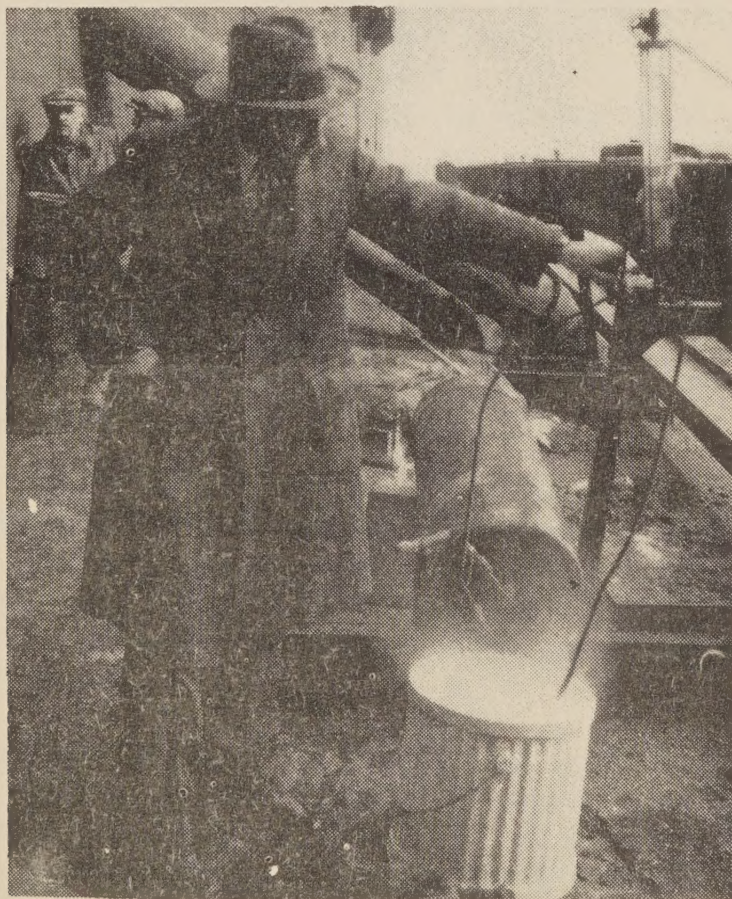


FIG. 4 - ETHYLENE OXIDE BEING MEASURED INTO CAN OF CRUSHED "DRY ICE" FROM TANK BY MEANS OF GLASS GAUGE. THIS METHOD IS MUCH SLOWER THAN BY WEIGHING AND SHOULD ONLY BE USED WHEN IT IS IMPRACTICAL TO WEIGH OUT THE MATERIAL







exchange, the members of the Department of Agriculture were enabled to observe the results of several commercial fumigations conducted by him with ethylene oxide and "dry ice." The results of these fumigations are included in tests 4 to 11.

In brief, the process consists of mixing together ethylene oxide and "dry ice" in large pails and introducing the mixture into the grain as it is being run into the bin. The mixture is carried down with the grain and is well distributed through it. It soon changes to a vapor that quickly kills all weevil life.

As previously indicated, "Dry ice" is really carbon dioxide in solid form. It is a white solid, easily crushed, and has a temperature of  $-110^{\circ}\text{F}$ . On exposure to air it slowly changes from a solid to a vapor. In Figure 1 is shown a 40-pound block of the "dry ice" ready for use. For fumigation purposes a special type of "dry ice" is used that is not compressed so much as the ordinary type. It has the consistency of chalk and is very easily crushed. If necessary, the ordinary "dry ice" can be used. It is delivered in insulated boxes that prevent excessive evaporation. It is prepared for use by being broken into small pieces with a sledge and ice pick, as shown in Figures 2 and 3, and shovelled into garbage pails that will hold about 70 pounds each when full. Since the "dry ice" evaporates at the rate of about 5 per cent by weight per day in the boxes in which it is obtained, it should not be ordered ahead of time, but only after the ethylene oxide is on hand, so that the fumigation can proceed as soon as the "dry ice" arrives. Somewhat more than the quantity needed for the fumigation must be purchased in order to allow for this evaporation. Since "dry ice" has a temperature of  $-110^{\circ}\text{F}$ ., it should not be handled with bare hands. If carelessly handled it is likely to blister the skin.

The ethylene oxide is poured over the crushed "dry ice" at the rate of 1 pound to 10 pounds of the "dry ice." It may be measured out of the cylinder by the use of a gauge, as shown in Figure 4, or weighed out as shown in Figure 3. Weighing out the ethylene oxide by use of a platform scale is a much quicker method than by measuring it with a gauge, and should be used whenever possible. The ethylene oxide can be forced out of the tank or cylinder by air pressure created with a small bicycle pump.

The mixture should be stirred a little so that all the liquid will be taken up by the "dry ice." The placing of a small quantity of elevator dust in the bottom of the pails before the "dry ice" is put in will prevent the collection of free liquid in the pail. Owing to the possibility of loss through evaporation, the materials should not be mixed in large quantities ahead of time, but only as needed.

The mixture is now ready to be carried to the bin floor of the elevator, where it should be applied without delay. It may be applied by shovelling it into the grain stream, as shown in Figure 5, or by use of a machine similar to the one shown in Figures 6 and 7. This machine can be regulated to any speed desired and feeds the mixture into the bin by means of a worm drive.



If the speed at which the grain is being run into the bin is known, it is a simple matter to figure out the rate at which the fumigant should be applied in order to obtain dosage of 33 pounds of the mixture per 1,000 bushels of grain. For example, if the wheat is run into the bin at the rate of 12,000 bushels an hour, a 66 pound batch of the fumigant will be fed into the grain stream during every 10 minute period.

In order to counteract leakage at the bottom and top of a bin, the dosage for the first 1,000 bushels and the last 500 bushels is made proportionally greater than for the rest of the bin. For example, in a 15,000 bushel bin, 66 pounds of the mixture is used for the first 1,000 bushels and 33 pounds of the mixture for the last 500 bushels. The dosage for the rest of the bin should be made slightly less than 33 pounds of the mixture per 1,000 bushels of grain in order to have an average of 33 pounds per 1,000 bushels for the entire bin.

Where the bin is open at the top it is desirable to cap off the grain with a layer of the ethylene oxide-"dry ice" mixture in order to insure a perfect kill in the upper layer of grain. As an illustration, a bin having a cross-section area of 200 square feet should receive an extra 66 pounds of the mixture as a top covering. It is also desirable to fill such a bin only to within 10 or 12 feet of the top so that a pocket of air will be present between the surface of the grain and the top of the bin, thus preventing excessive loss of the fumigant.

When the fumigant is applied by shovelling the ethylene oxide-"dry ice" into the grain stream, it will be found convenient to dump the mixture into an open ended box placed near the mouth of the bin. This insures a better mixture and makes it easier to shovel it into the bin. In applying the fumigant by this method the operator unavoidably inhales more or less of the gas. The inhalation of small quantities of the gas is not harmful to the operator, but prolonged exposure to the fumes is likely to cause severe nausea, particularly in the presence of a heavy dust. It is therefore well to assign two men to the task of shovelling, so that they can alternate in the application of each batch of the mixture. Should an employee become nauseated from too long an exposure to the fumes, the discomfort is only temporary and no further ill effects need be feared.

#### Observation on Commercial Fumigations of Grain in

##### Elevator Bins

##### Fumigation No. 1

Condition of fumigation.- Location: Jersey City, N. J. Type of bin: Concrete, 80 feet deep, open at top, spout gate unsealed. Grain: 3,500 bushels rye, heavily infested with the granary weevil. Treatment: 2 pounds ethylene oxide and 14 pounds of "dry ice" per 1,000 bushels grain applied to grain as it was run into the bin. Temperature of grain before fumigation, 70° F.; after fumigation, 64° F.; air temperature, 52° F. Length and time of exposure:



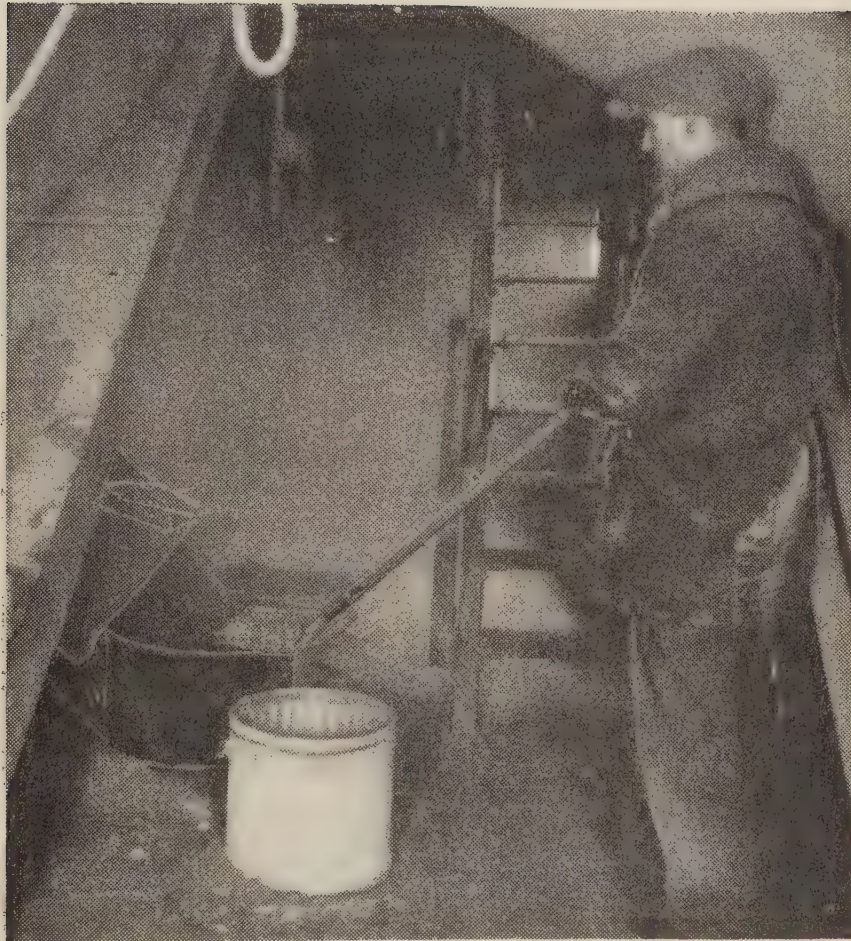


FIG. 5 - SHOVELLING THE MIXTURE OF ETHYLENE OXIDE AND "DRY ICE" INTO THE GRAIN STREAM AS THE WHEAT IS BEING RUN INTO THE BIN. IF THIS METHOD IS USED IT WILL BE FOUND ADVANTAGEOUS TO DUMP THE MIXTURE INTO AN OPEN-ENDED WOODEN BOX BEFORE SHOVELLING INTO THE BIN







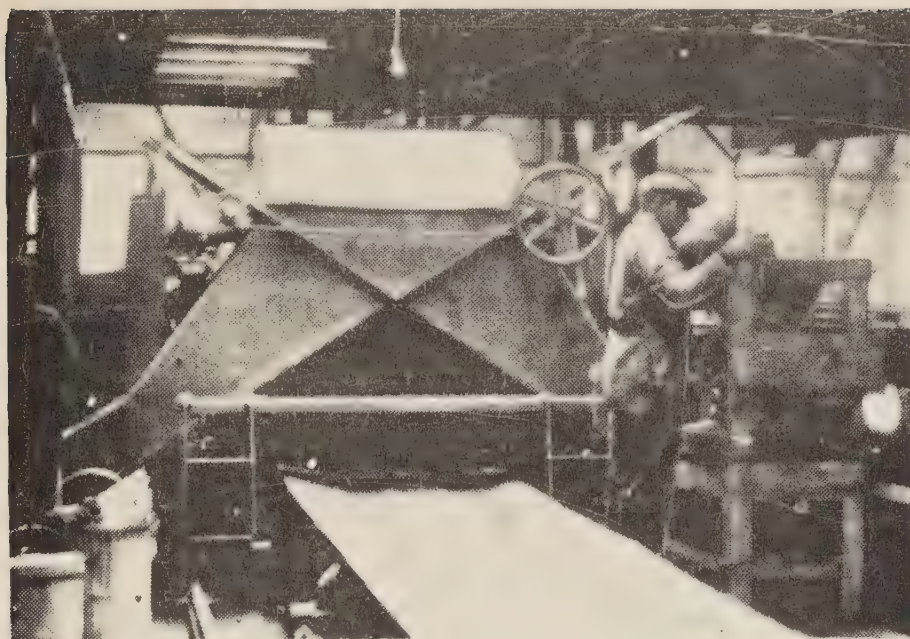


FIG. 6 - THE MACHINE FOR AUTOMATICALLY APPLYING THE MIXTURE OF ETHYLENE OXIDE AND "DRY ICE" IS SHOWN IN PLACE NEAR THE TRIPPER. THE OPERATOR IS PREPARING TO DUMP A BATCH OF THE MIXTURE INTO THE HOPPER OF THE MACHINE



FIG. 7 - THE AUTOMATIC APPLICATOR IS SHOWN FEEDING A STREAM OF THE MIXTURE OF ETHYLENE OXIDE AND "DRY ICE" INTO THE STREAM OF GRAIN AS IT COMES FROM THE TRIPPER. THE FUMIGANT SHOWS AS A LIGHT STREAK ON THE SURFACE OF THE GRAIN STREAM







48 hours, October 23-30. Insect used: Rice weevil, Sitophilus oryza, planted at equal intervals throughout the bin, from 10 to 100 insects placed in each bag.

Results.- Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 65 per cent; No. 2, 100 per cent; No. 3, 97 per cent; No. 4, 95 per cent; No. 5, 100 per cent; No. 6, 100 per cent; No. 7 (at top of bin), 55 per cent. Composite sample showed 89 per cent kill after treatment.

#### Fumigation No. 2

Conditions of fumigation.- Location: Norfolk, Va. Type of bin: Concrete, 90 feet deep. Grain: 15,000 bushels of wheat. Treatment: 2.2 pounds ethylene oxide and 16 pounds of "dry ice" per 1,000 bushels of grain. Temperature of grain before fumigation, 75° F.; after fumigation, 63° F.; air temperature, 35° F. Length and time of exposure: 8 days, December 2-10. Insect used: Rice weevil, planted at equal intervals throughout the bin, from 10 to 100 insects placed in each bag.

Results.- Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 100 per cent; No. 2, 35 per cent; No. 3, 84 per cent; No. 4, 88 per cent; No. 5, 100 per cent; No. 6, 100 per cent; No. 7, 100 per cent, No. 8, 100 per cent; No. 9, 100 per cent; No. 10, (at top of bin), 100 per cent. Composite sample showed 98 per cent kill after fumigation.

#### Fumigation No. 3

Condition of fumigation.- Location: Newport News, Va. Type of bin: Wood, 90 feet deep. Grain: 10,000 bushels wheat. Treatment: 2.3 pounds ethylene oxide and 20 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 73° F; after fumigation, 67.8° F.; air temperature, 28° F. Length and time of exposure: 7 days, December 3-10. Insect used: Rice weevil, planted at equal intervals throughout the bin, from 10 to 100 insects placed in each bag.

Results.- Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 86 per cent; No. 2, 67 per cent; No. 3, 66 per cent; No. 4, 86 per cent; No. 5, 100 per cent; No. 6, 100 per cent; No. 7, 100 per cent, No. 8 (at top of bin), 100 per cent. Composite sample showed 90.9 per cent kill after fumigation.

#### Fumigation No. 4

Conditions of fumigation.- Location: New York, N. Y. Type of bin: concrete, 90 feet deep. Grain: 14,000 bushels wheat. Treatment: 3 pounds ethylene oxide and 27 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 55-88° F; after fumigation, 48-70° F; Length of exposure 12 days. Insect used: Rice weevil, planted at equal intervals throughout bin, from 10 to 100 insects in each bag.

Results.- Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 100 per cent; No. 2, 100 per cent; No. 3, (2 "bran bugs" alive), 100 per cent; No. 4, 100 per cent; No. 5, 100 per cent, No. 6, (at top of bin), 100 per cent. Composite sample showed 97.2 per cent after treatment.



### Fumigation No. 5

Conditions of fumigation.— Location: New York, N. Y. Type of bin: Concrete, 90 feet deep. Grain: 15,000 bushels wheat. Treatment: 3 pounds ethylene oxide and 30 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 58-62° F. Insect used: Rice weevil, planted at equal intervals throughout the bin, from 10 to 100 insects placed in each bag.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 33.3 per cent (on gate of bin); No. 2, 100 per cent; No. 3, 100 per cent; No. 4 (at top of bin), 100 per cent; Composite sample showed 100 per cent kill after fumigation.

### Fumigation No. 6

Condition of fumigation:— Location: New York, N. Y. Type of bin: Concrete, 90 feet deep. Grain: 15,000 bushels wheat. Treatment: 3 pounds ethylene oxide and 30 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 58-62° F. Insect used: Rice weevil planted in bags of grain throughout bin.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1 (at bottom of bin), 100 per cent; No. 2, 100 per cent; No. 3, 100 per cent; No. 4 (at top of bin), 100 per cent. Composite sample showed 100 per cent kill after fumigation.

### Fumigation No. 7

Conditions of fumigation.— Location: Buffalo, N. Y. Type of bin: Concrete, 85 feet deep, closed top. Grain: 40,000 bushels wheat. Treatment: 3 pounds ethylene oxide and 30 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 42-50° F.; air temperature, 45° F. Insect used: Rice weevil, planted in bags of grain throughout bin.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1, 100 per cent, No. 2, 100 per cent; No. 3, 100 per cent; No. 4, 100 per cent. Composite sample showed 100 per cent kill after fumigation.

### Fumigation No. 8

Conditions of fumigation.— Location: Buffalo, N. Y. Type of bin: Concrete, 85 feet deep, closed top. Grain: 40,000 bushels wheat. Treatment: 3 pounds oxide and 30 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain treatment, 42-50° F.; air temperature in elevator, 45° F.; outside, 37° F. Insect used: Rice weevil planted in bags of grain throughout bin.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1, 100 per cent; No. 2, 100 per cent; No. 3, 100 per cent; No. 4, 100 per cent. Composite sample showed 100 per cent kill after fumigation.



### Fumigation No. 9

Conditions of fumigation.— Location: Buffalo, N. Y. Type of bin: Steel tank, closed on top. Grain: 12,000 bushels wheat. Treatment: 4.6 pounds ethylene oxide and 46 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 48–59° F; air temperature, 28° F. Insect used: Rice weevil planted in bags of grain throughout bin.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1, 100 per cent; No. 2, 100 per cent; No. 3, 100 per cent. Composite sample showed 100 per cent kill after fumigation.

### Fumigation No. 10

Conditions of fumigation.— Location: Buffalo, N. Y. Type of bin: Concrete, 85 feet deep, closed on top. Grain: 12,000 bushels wheat. Treatment: 3.5 pounds ethylene oxide and 35 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before fumigation, 47–54°F.; air temperature, 29° F. Insect used: Rice weevil, planted in bags of grain throughout bin.

Results:— Planted bags and per cent of weevils killed in each bag: No. 1, 100 per cent; No. 2, 100 per cent; No. 3, 100 per cent; No. 4, 100 per cent; No. 5, 100 per cent; No. 6, 100 per cent; No. 7, 100 per cent; No. 8, 100 per cent, No. 9, 100 per cent; No. 10, 100 per cent. Composite sample showed 100 per cent kill after fumigation.

### Fumigation No. 11

Conditions of fumigation.— Location: Buffalo, N. Y. Type of bin: Concrete, 85 feet deep, closed on top. Grain: 12,000 bushels wheat. Treatment: 3.5 pounds ethylene oxide and 35 pounds of "dry ice" per 1,000 bushels grain. Temperature of grain before treatment, 44–55° F.; air temperature, 31° F. Insect used: Rice Weevil, planted in bags of grain throughout bin.

Results.— Planted bags and per cent of weevils killed in each bag: No. 1, 100 per cent; No. 2, 100 per cent; No. 3, 100 per cent. Composite sample showed 100 per cent kill after fumigation.

### Milking and Baking Tests

Eight milling and baking tests were made of lots of wheat before and after treatment with ethylene oxide and mixtures of ethylene oxide and "dry ice." The results of these tests are given in Table I. The first lots represent wheat from large elevator bins. Lot 1 represents samples taken from approximately 13,000 bushels of wheat before treatment with the fumigant; lot 2 represents samples taken from the same bin after treatment with ethylene oxide and "dry ice." Lot 3 represents samples taken from approximately 10,000 bushels of wheat before fumigation, and lot 4 represents samples taken from the same bin after fumigation with ethylene oxide and "dry ice." Lots 5 and 8 represent one large sample that was mixed thoroughly and divided into four equal lots. Lot 5 was not treated, lot 6 was treated with ethylene oxide at the rate of



Table I. - Milling and Baking Tests with Wheat before and after Treatment with Ethylene Oxide and Mixtures of Ethylene Oxide and "Dry Ice"

Lot num-	Flour yield	Loaf		Differ- ence in volume	Differ- ence from check	Grain Text- ure	Color of crumb	Color of crust	Ash	Pro- tein		Moist- ure	Treatment	Number of bushels
		P.ct.	C.c.							P.ct.	P.ct.			
1	70.2	520	(1)	-	-	78 F	78 gr	Pale	.49	9.74	13.10	(2)	(2)	15,000
2	71.8	523	+ 3.0	.56	.56	88 G	78 gr	L.B.	.50	9.72	12.76	2.2 lbs. ethylene oxide, 16 lbs. CO <sub>2</sub> per 1,000 bu.	2.2 lbs. ethylene oxide, 16 lbs. CO <sub>2</sub> per 1,000 bu.	15,000
3	70.8	513	(1)	-	-	88 G	80 cr	L.B.	.48	9.52	12.81	(2)	(2)	10,000
4	70.4	520	+ 7.0	1.37	1.37	80 F	80 cr	L.B.	.48	9.45	13.02	2.3 lbs. ethylene oxide, 20 lbs. CO <sub>2</sub> per 1,000 bu.	2.3 lbs. ethylene oxide, 20 lbs. CO <sub>2</sub> per 1,000 bu.	10,000
5	72.5	505	(1)	-	-	72 P	80 cr	L.B.	.49	10.95	12.32	(2)	(2)	(3)
6	72.6	497	- 8.0	-1.60	-1.60	75 P	75 gr	B.	.49	11.01	11.99	2 lbs. ethylene oxide per 1,000 cu. ft. of space	2 lbs. ethylene oxide per 1,000 cu. ft. of space	(3)
7	72.4	497	- 8.0	-1.60	-1.60	80 G	80 cr	L.B.	.49	10.86	12.41	3 lbs. ethylene oxide per 1,000 cu. ft. of space	3 lbs. ethylene oxide per 1,000 cu. ft. of space	(3)
8	71.2	503	- 2.0	-0.40	-0.40	78 F	80 cr	L.B.	.50	10.92	12.92	4 lbs. ethylene oxide per 1,000 cu. ft. of space	4 lbs. ethylene oxide per 1,000 cu. ft. of space	(3)

(1) - Check.

(2) - Tests were made before treatment.

(3) - Laboratory sample.



2 pounds per 1,000 cubic feet, lot 7 was treated with ethylene oxide at the rate of 3 pounds of ethylene oxide per 1,000 cubic feet, and lot 8 with 4 pounds of ethylene oxide per 1,000 cubic feet.

As may be seen by referring to Table I, no impairment of the milling and baking qualities of these samples of wheat resulted from the treatment with ethylene oxide.

#### Odor

No odor of the chemicals used was left on any of the foregoing samples tested. In addition, a large number of samples of wheat taken after fumigation with ethylene oxide and "dry ice," representing large commercial lots, have been examined and no odor detected on any of them.

#### Germination Tests

Germination tests of wheat fumigated on a laboratory scale with ethylene oxide alone led to the conclusion that its germination was seriously impaired by the treatment. Roark and Cotton (U.S.D.A. Tech. Bil. 162) and Young (Jour. Agr. Res. v. 39, no. 12) report no germination of wheat so treated. When, however, wheat in bulk was treated with a mixture of ethylene oxide and carbon dioxide, the germination was found to have been little affected. Germination tests were made with composite samples taken from bins of wheat before and after commercial fumigations with a mixture of ethylene oxide and carbon dioxide. The results of these tests, given in Table II, indicate that the fumigation of bulk grain with this mixture does not materially affect its germination.

If small quantities of wheat are fumigated in large containers (where the quantity of fumigant is relatively large in proportion to the quantity of grain) the absorption of ethylene oxide undoubtedly seriously injures the germination. It would therefore seem unwise to fumigate by this method small quantities of wheat intended for seed.



Table II. - Germination Tests of Wheat Fumigated with Ethylene Oxide and Carbon Dioxide

Source of sample	Quantity of fumigant per 1,000 bushels	Quantity of wheat fumigated	Germination before fumigation	Germination after fumigation
Washington, D. C.	2( lbs. ethylene oxide and 22½ lbs. carbon dioxide	<u>Bushels</u> (1/)	<u>Per cent</u> 93	<u>Per cent</u> 93
Norfolk, Va.	2.2 lbs. ethylene oxide and 16 lbs. carbon dioxide	15,000	56	42
Newport News, Va.	2.3 lbs. ethylene oxide and 20 lbs. carbon dioxide	10,000	82	76
Buffalo, N. Y.	3.5 lbs. ethylene oxide and 35 lbs. carbon dioxide	12,000	68	60
Buffalo, N. Y.	3.5 lbs. ethylene oxide and 35 lbs. carbon dioxide	12,000	82	68
Buffalo, N. Y.	4.6 lbs. ethylene oxide and 46 lbs. carbon dioxide	12,000	84	56
Buffalo, N. Y.	3 lbs. ethylene oxide and 30 lbs. carbon dioxide	40,000	40	30
Buffalo, N. Y.	3 lbs. ethylene oxide and 30 lbs. carbon dioxide	40,000	31	36

1/ Laboratory samples.